In the outstanding Office Action, the specification was objected to under 37 CFR 1.71 for containing informalities; Claims 15-18 were rejected under 35 U.S.C. §112, first paragraph; and Claims 15-18 were rejected under 35 U.S.C. §102(b) as being unpatentable over Radjai et al. ("Effects of Electromagnetic ...").

In response to the objection to the specification, the specification has been amended to correct the noted informalities. Applicants submit that no new matter has been introduced.

In response to the rejection of Claims 15-18 under 35 U.S.C. §112, first paragraph, Claims 15 and 18 have been amended to further clarify the claimed invention. Accordingly, Applicants believe that Claims 15-18, as amended, are definite and comply with the requirements of 35 U.S.C. §112.

Recapitulating briefly, the present invention is directed to a method for refining the microstructure of metallic materials.[1] As recited in amended independent Claim 15, features of the present invention include subjecting the molten metallic material to a solidification process at temperatures lower than a liquidus of the molten metallic material, applying a high-energy vibrating force including one of an electromagnetic vibrating force and an ultrasonic vibrating force to the metallic material during a solidification process at temperatures lower than the liquidus of the molten metallic material to form cavities in the molten metallic material, and crushing into small pieces, via impact pressure generated during collapse of the cavities, solid crystals of the metallic material generated during the solidification process to yield a refined microstructure of the metallic material. An advantage of the present invention over the background art is that metals, intermetallic compounds, and solid particulate ceramics can be dispersed and crushed in the solid metal.[2]

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[1]Specification, page 1, lines 8-9, for example.

[2]Specification, page 10, lines 5-10, for example.

Attention is now directed to the patentability of amended independent Claim 15 over the Radjai et al. reference.

The Radjai et al. reference discloses:

"Vibrations were induced in a hyper-eutectic A1-Si alloy containing suspended silicon particles and the effects were studied;"

"The mechanism by which vibrations bring about microstructural changes was investigated by interrupting the process at different temperatures before and after the start of solidification through water quenching;" and

"Suspended silicon particles multiplied in number with a reduction in size by vibrations at temperatures higher than the liquidus and agglomerated and repelled to the outer surface after start of solidification."

In view of the above, the following comments point out differences between the Radjai et al. reference and the claimed invention.

An experimental apparatus enabling the simultaneous application of alternating electric and stationary magnetic fields, under different cooling conditions ranging from rapid to furnace cooling, was used to study the mechanism by which electromagnetic vibrations affect the solidification structure of an A1-Si alloy system.

In the figure in the Appendix to the present Amendment, A and C show the temperatures of the liquidus and B and D show the temperatures of the solidus of the A1-Si alloy system.

In Radjai et al., the two fields were applied simultaneously and suspended silicon particles multiplied in number with a reduction in size by vibration at temperatures higher than the liquidus and agglomerated and repelled to the outer surface after the start of solidification.

This means that the two fields were applied to the hyper-eutectic A1-Si alloy containing suspended silicon particles simultaneously at temperatures higher than the temperature of the liquidus A, and suspended silicon particles were agglomerated and repelled to an outer surface after the start of solidification at the temperatures between the liquidus A and solidus B.

On the other hand, in the claimed invention, the molten metallic material is subjected to a solidification process at temperatures lower than the liquidus A and a high-energy vibrating force is applied to the metallic material during the solidification process, that is at the temperatures lower than the liquidus B.

As noted above, in Radjai at al the two fields were applied to the sample at temperatures higher than the liquidus, and in contrast, in the claimed invention, the high-energy vibrating force is applied to the sample at temperatures lower than the liquidus. Therefore, the subject matter of the claimed invention is clearly distinguished from the invention described in Radjai et al.

In consideration of the above matter, in order to more particularly point out and distinctly claim the subject matter which Applicants regard as the claimed invention, Applicants have amended claims as described above.

The Official Action indicates that "Radjai et al. do show to apply a EM vibrating force to an alloy system before and after the start of solidification process. Thus, the claimed invention reads on the prior art reference" (emphasis added).

However, as explained above, in Radjai et al., which states "[s]uspended silicon particles multiplied in number with a reduction in size by vibration at temperatures higher than the liquidus and agglomerated and repelled to the outer surface after the start of solidification," the vibration force is applied to the alloy system at temperatures higher than

the liquidus, and the suspended silicon particles were agglomerated and repelled to the outer surface after the start of solidification. Therefore, it is apparent that an EM vibrating force to an alloy system in Radjai et al. is applied only before the start of solidification process, but is not applied after the start of solidification process, and that shows that the claimed invention excludes the feature of application of the vibrating force of Radjai et al., and the result of the Radjai et al. process is not the same as that of instant process.

Radjai et al. also state that "[t]he mechanism by which vibrations bring about microstructural changes was investigated by interrupting the process at different temperatures before and after the start of solidification through water quenching," which means that a vibrating force is applied to an alloy system at temperatures before the start of solidification and water quenching is applied at temperatures before and after start of solidification, which is apparent from the description that "[s]uspended silicon particles multiplied in number with a reduction in size by vibrations at temperatures higher than the liquidus and agglomerated and repelled to the outer surface after the start of solidification."

Therefore, the Radjai et al. reference does not disclose or suggest subjecting the molten metallic material to a solidification process at temperatures lower than the liquidus of the molten metallic material, applying a high-energy vibrating force including one of an electromagnetic vibrating force and an ultrasonic vibrating force to the metallic material during a solidification process at temperatures lower than the liquidus of the molten metallic material to form cavities in the molten metallic material, and crushing into small pieces, via impact pressure generated during collapse of the cavities, solid crystals of the metallic material generated during the solidification process to yield a refined microstructure of the metallic material, as recited in amended independent Claim 15.

Referring now to the figure in the Appendix, the claimed invention is further explained in detail by showing an example. Electromagnetic vibrations are induced in the A1-Si alloy during solidification by simultaneous application on the two fields.

For example, an experiment, which was carried out over wide ranges of intensity (an electromagnetic pressure range of 0 to 2.25 X 10^5 Pa) and frequency (0 to 50 KHz), clarified the effects of the two parameters on the microstructural refinement brought about by electromagnetic vibrations.

The electromagnetic vibrations induced in an A1-Si alloy melt during solidification by simultaneous application of alternating electric and stationary magnetic fields resulted in the collapse of the highly columnar dendritic structure into a fine and homogeneous structure composed of fragmented, equiaxed dendrites, and isolated grains.

Low-intensity vibrations resulted in a microstructure composed of large, equiaxed dendrites, which became smaller as the intensity and, consequently, the electromagnetic pressure was increased. At pressures higher than about 0.93 X 10^5 Pa, fine, isolated grains started to appear and dominated the structure as the pressure was increased further.

Investigating the effects of the frequency of vibrations, it was found that at low frequencies the effect is limited to suppressing the columnar structure and to formation of a microstructure with large, equiaxed dendrites. As the frequency was increased, dentrites started to disintegrate, resulting in a fine and homogeneous structure up to about 1.5 KHz.

The results obtained for higher frequencies showed that the trend gradually reversed and the microstructure became a completely columnar dendritic one at frequencies higher than 10 KHz.

After setting the sample in the apparatus, power was passed through the electrodes to melt the sample and heat it to 700°C. Samples could be melted without using the furnace

when graphite electrodes were used and an appropriate amount of electric current was passed through them, taking advantage of the joule heat generated in the electrodes and the sample. The temperature was kept at 700°C for 2 minutes before the current was switched off, depending on the experiment being carried out. Water was sprayed from the nozzles fixed on both sides of the sample for quenching. The figure in the Appendix is a phase diagram of Al-Si alloy and shows quenching temperature of Al-Si alloy sample.

As indicated in the figure in the Appendix, in the alloy system there exist temperatures of liquidus and solidus, wherein the sample is liquified at temperatures higher than the liquidus, the sample contains liquid and semi-solid at temperatures lower than the liquidus, that is between the liquidus and the solidus, and in view of the above and as a matter known in the technical field, to clarify that known matter, the term "melting point" has been deleted from the claims.

In view of the presently submitted amendments, the amended claims define the differences of the subject matter of the claimed invention and the invention described in Radjai et al.. Therefore, Applicants respectfully submit that the present amendment overcomes the outstanding rejections.

Consequently, in view of the present amendment, no further issues are believed to be outstanding in the present application, and the present application is believed to be in condition for formal allowance. An early and favorable action is therefore respectfully requested.

Respectfully submitted,

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IN THE SPECIFICATION

Page 8, at lines 13-18, please delete the paragraph and replace it with the following paragraph:

As used herein, the term “molten metal” refers to a metal that is completely liquified [which] when kept at a temperature above its melting point. In addition, the term “solidifying metal” refers to a liquid containing solid metal crystals that form at a temperature [below the melting point] between the liquidus temperature and the solidus temperature.

IN THE CLAIMS

Please amend Claims 15 and 18 as shown below.

--15. (Amended) A method for [refining a] producing a refined microstructure of a metallic material, comprising:

subjecting the molten metallic material to a solidification process at temperatures lower than a liquidus of the molten metallic material;

applying a high-energy vibrating force including one of an electromagnetic vibrating force and an ultrasonic vibrating force to the metallic material [at temperatures lower than a melting point thereof] during a solidification process at temperatures lower than the liquidus of the molten metallic material to form cavities in the molten metallic material; and

crushing into small pieces, via impact pressure generated during collapse of the cavities, solid [particles] <u>crystals</u> of the metallic material generated during the solidification process to yield a refined microstructure of the metallic material.

18. (Amended) The method of Claim 15, wherein a high-energy vibrating force is applied to the metallic material at temperatures lower than [a melting point] <u>liquidus</u> thereof during last stages of the solidification process.--